Fraser River Action Plan Assessment of Contaminant Effects on Aquatic Ecosystems

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Introduction

The Fraser River Basin is the largest river basin in the province of British Columbia, Canada, draining an area of 234,000 km^2. The basin has significant environmental and commercial value to the province. It supports the largest natural salmon run in the world and the estuary/delta comprises part of the Pacific Flyway for migratory birds. The Fraser River Action Plan (FRAP) is a major ecosystem-wide initiative led by the federal government in Canada to promote the sustainability of the ecological and societal health in the basin. The Plan has several objectives and one was to clean up and prevent pollution in the aquatic ecosystem. A major component of achieving this objective was to assess the current condition of the aquatic ecosystem and its response to contaminants.

Exposure to contaminants has been measured in the basin's aquatic ecosystem through previous studies. For example, elevated levels of dioxins and furans have been measured in sediment and fish in the late 1980s and early 1990s (Mah et al., 1989; Dwernychuk et al., 1991) and elevated levels of chlorophenolics have been recorded for sediment (Swain and Walton 1988) and water (Drinnan et al., 1988; Carey et al., 1988) from sampling conducted in the 1980s.

The FRAP Environmental Quality program utilized four key components of the aquatic ecosystem to track contaminant exposure. The media used were: water, suspended and bed sediment, fish and aquatic-based wildlife. The effects of contaminants and other stressors on the ecosystem were studied in fish, benthic macroinvertebrates and aquatic-based wildlife (birds and mammals). Figure 1 presents the distribution of sampling sites for these media throughout the basin.

For this paper, examples of contaminant results related to suspended sediment, bed sediment and fish tissue from the lower Fraser River and estuary will be presented.

Methods

Sampling of suspended sediment, bed sediment and fish was conducted from 1992 to 1997 at several reaches throughout the basin. Figure 2 presents reaches sampled in the lower Fraser: Agassiz-Lytton reach at the head of the lower Fraser valley, and the North and South arms in the estuary. The Lytton-Quesnel reach (Figure 1) was used as an upstream reference area for comparison to contaminant concentrations measured in the lower Fraser. All media were sampled from the same reaches, where possible.

Suspended sediment was sampled using continuous flow centrifuges; usually one time integrated sample was collected during each sampling campaign per site. Bed sediments were sampled with Ekman grabs from sediment deposition areas in the rivers and four replicate samples were collected per reach. Fish were sampled using beach seines. Fish liver samples consisted of either one or two composite samples per reach; fish muscle samples consisted of five composite samples per reach. Samples were analysed for the following classes of contaminants: dioxins, furans, polychlorinated biphenlys (PCBs), chlorophenolics, polycyclic aromatic hydrocarbons (PAHs), organochlorine pesticides, resin and fatty acids, nonylphenolics and trace metals. These were substances that were known or suspected to be associated with known sources in the basin. Details on methods associated with sampling for suspended sediment, bed sediment and fish are presented in Sekela et al. (1995), Brewer et al. (in prep.) and Raymond et al. (in prep.), respectively.

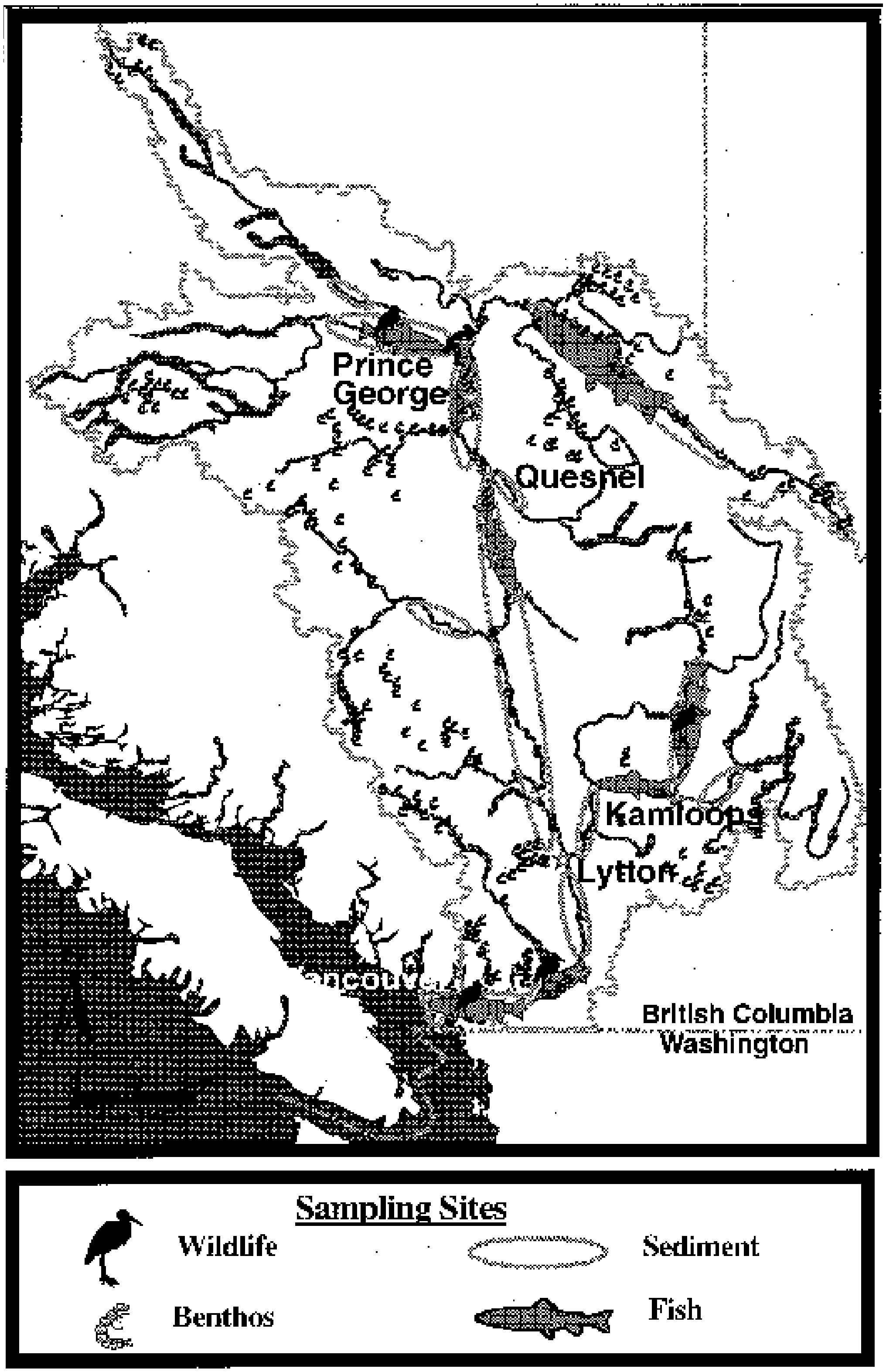

Figure 1. Distribution of sampling sites in the Fraser River Basin.

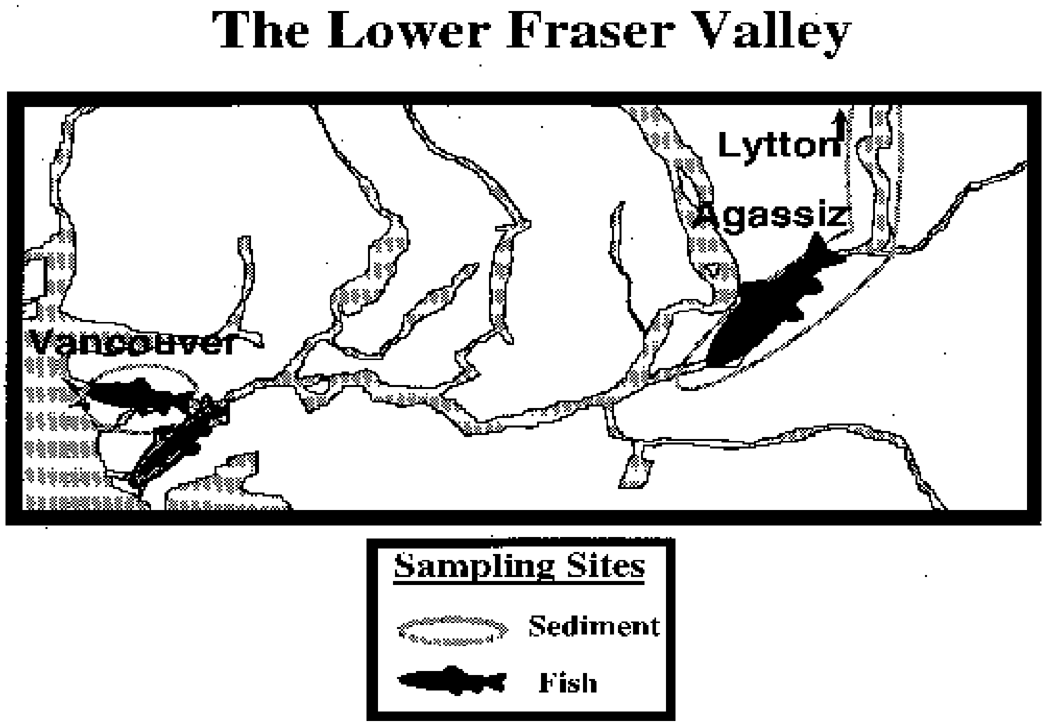

Figure 2. Sampling reaches in the lower Fraser River.

Results and Discussion

The levels of most contaminants in suspended sediment (when expressed as concentration in water), bed sediment and fish tissue from the lower Fraser River were low compared to available Canada Council of Ministers of Environment (CCME) guidelines (CCME, 1994, 1995; CCREM, 1987) and British Columbia Ministry of Environment Lands and Parks (BCMELP) criteria (BCMELP, 1995) for the protection of freshwater life. This is consistent with results found elsewhere in the basin. However, for some classes of contaminants, higher levels were measured in the Fraser estuary than at most most other locations in the basin. In bed and suspended sediment, this was observed for PAHs, dioxins and furans, PCBs, organochlorine pesticides and some metals (arsenic for suspended sediment; arsenic, copper, zinc and lead for bed sediment). Fish tissues had higher levels of organochlorine pesticides and PCBs in the lower Fraser. As well, peamouth chub (*Mylocheilus caurinus*) from the estuary had higher levels of PAHs in liver tissues than fish collected toward the head of the lower Fraser valley. PAHs in fish were analysed only in the lower Fraser.

As an example of the spatial profile of contaminants in the lower Fraser, results on PAHs, dioxins and furans in the three media will be presented here. Detailed results and discussions on all contaminants are presented in Sylvestre et al, (in prep.), Brewer et al. (in prep.) and Raymond et al. (in prep.).

Total parent PAH concentrations in suspended sediment, bed sediment and peamouth chub liver are presented in Figure 3. All three media show the same pattern—higher concentrations in the estuary, with the highest levels measured in the North Arm. Suspended sediment levels for the individual PAH compounds comprising the total parent PAH group, expressed as water concentrations, did not exceed any Canadian water quality guidelines or B.C. water quality criteria for the protection of freshwater life. Bed sediment concentrations exceeded sediment quality guidelines or criteria for the protection of freshwater life for some individual PAH compounds at all sites, the greatest number of exceedences (8) occurred in the North Arm reach.

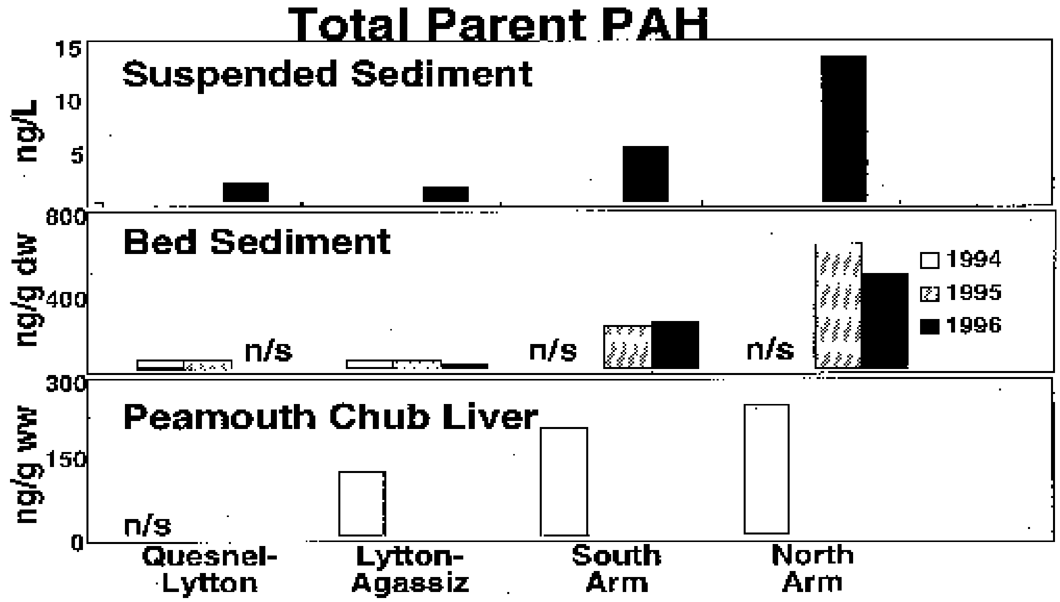

Figure 3. Concentrations of Total Parent PAHs in suspended sediment (expressed as ng/L water), bed sediment and peamouth chub liver from lower Fraser River reaches, and from the upstream Quesnel-Lytton reach. Concentrations in suspended sediment represent a single time integrated sample; concentrations in bed sediment are the mean of four replicates; concentrations of liver represent a single composite value or the mean of two composites. n/s denotes not sampled.

Higher concentrations in the North Arm are likely due to the diminished ability for dilution of inputs by the river, as the North Arm carries about 12% of the river flow at the division of the main stem of the river to North and South Arms (FREMP, 1996). Other factors contributing to the higher PAH levels in the North Arm are likely the presence of combined sewer inputs, as well as a greater number of stormwater discharges, relative to the South Arm (FREMP, 1996). The North Arm is surrounded by dense urban development. Known sources of PAHs include many related to urban activities, such as urban runoff (Boom and Marselek, 1988), combustion of organic material, industrial combustion, wood burning and automobile exhaust (Water Quality Branch, 1993).

Dioxin and furan exposure in suspended and bed sediment shows the same spatial pattern as PAHs—highest concentrations in the North Arm (Figure 4). The concentration in suspended sediment (expressed as pg/L water) approaches the CCME interim water quality guideline for the protection of freshwater life (CCME ,1995). All the bed sediment levels in the lower Fraser River exceed the CCME interim sediment quality guideline. Several other sites elsewhere in the basin also exceeded this interim guideline. Brewer et al . (in prep.) suggest that the dominance of octachlorodibenzoparadioxin (OCDD) in the congener profile for both bed and suspended sediment in the lower Fraser River indicate that combustion sources (Czuczwa and Hites, 1986) are significant contributors of these contaminants in the estuary. The North Arm congener signal (combination of hepta- and octa-dioxins and furans) is also consistent with a pentachlorophenal source (Czuczwa and Hites, 1986), possibly a remnant of past pentachlorophenal usage at lumber mills in the North Arm (Brewer et al., in prep.).

Dioxin and furan concentrations in peamouth chub muscle show low levels and a similar pattern to the sediment data. The levels are well below the CCME interim wildlife dietary guideline (CCME, 1995). The major contributor to the toxic equivalent unit is the 2,3,7,8-tetrachlorodibenzofuran congener (Raymond et al., in prep). This suggests remnants of past contamination and possibly low level current contamination from upstream pulp mills (Amendola,1987). In 1991 basin pulp mills were required to change their bleaching process by substituting chlorine dioxide for elemental chlorine to reduce the discharge of dioxins and furans to the environment.

Dioxin and furan concentrations show decreases when compared to pre-1991 data. Large decreases are seen in bed sediment levels in the upstream Lytton to Quesnel reach, where concentrations were up to about 42 pg/g Toxic Equivalent Unit (TEQ) in 1988 (Mah et al., 1989). Levels at that reach were at 0.05 pg/g TEQ in the current study. Bed sediment concentrations in the estuary are similar to those measured prior to 1991 (Brewer et al., in prep.). Pre-1991 concentrations in peamouth chub muscle were measured at 15 pg/g TEQ in the upstream reach in 1988 (Mah et al., 1989). In the estuary, concentrations were about 2 pg/g TEQ in peamouth chub collected in 1989 (Tuominen and Sekela, 1992). Concentrations today are less than 0.14 pg/g TEQ, more than an order of magnitude lower than pre-1991 levels.

Decreases in other contaminants, such as PCBs, pentachlorophenol, organochlorine pesticides and lead, relative to pre-1991 levels were also found in the lower Fraser (Brewer et al., in prep; Raymond et al., in prep.; FREMP, 1996). These decreases are due to the introduction of regulations to control their use or discharge to the environment.

The increase in concentration of contaminants in the estuary, relative to other basin areas, is attributed to human activities in the surrounding urban landscape. This effect was more pronounced in a FRAP study conducted in an urban tributary of the estuary. Because of less dilution potential in the tributary, even higher concentrations of the same contaminant classes (e.g., PAHs, dioxins and furans) were measured in the tributary's aquatic ecosystem than in the Fraser River (Sekela et al., in prep.).

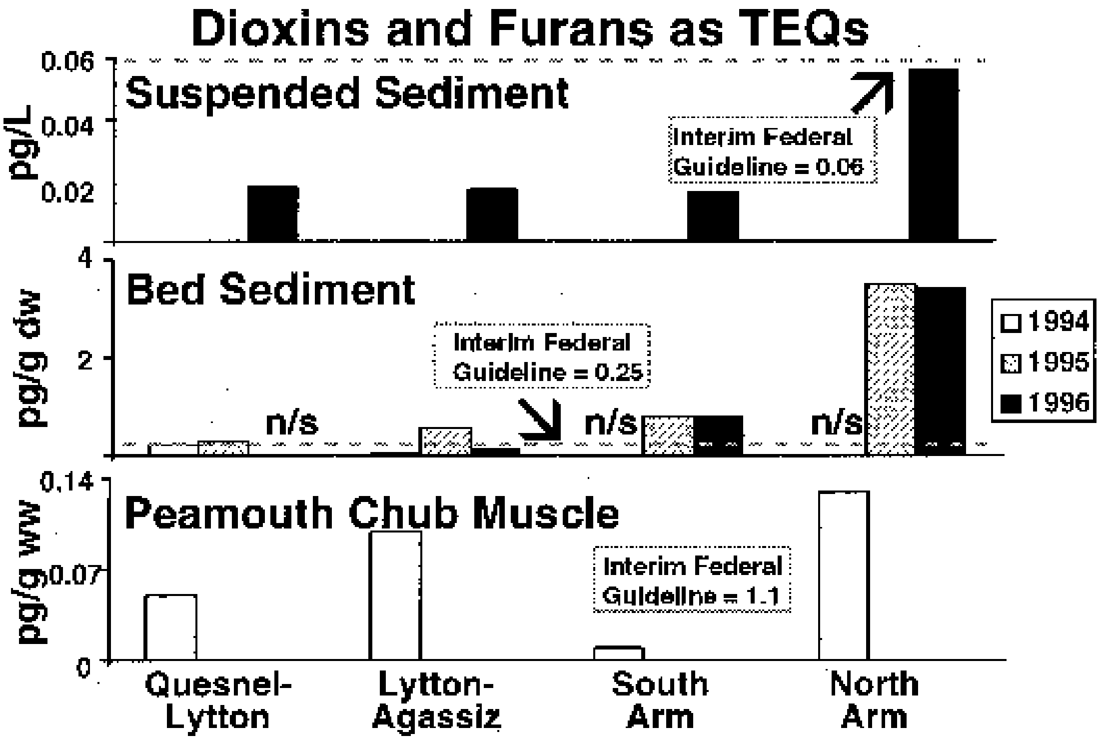

Figure 4. Concentrations of dioxins and furans, as 2,3,7,8-tetrachlorodibenzo-para-dioxin Toxicity Equivalent Units, in suspended sediment, bed sediment and peamouth chub muscle tissue from lower Fraser River reaches, and from the upstream Quesnel-Lytton reach. Concentrations in suspended sediment are expressed as pg/L water and represent a single time integrated sample; concentrations in bed sediment are the mean of four replicates; concentrations in muscle are the mean of five composite samples. n/s denotes not sampled.

Conclusions

1. Most contaminants in suspended sediment (expressed as concentration in water), bed sediment and fish tissue from the lower Fraser River were measured at low levels compared to Canadian federal guidelines and provincial criteria for the protection of freshwater life. This was consistent to results found elsewhere in the basin. Exceptions included PAHs in bed sediment from the estuary and dioxins and furans in bed and suspended sediment from the estuary.
2. Concentrations of some contaminants, such as pentachlorophenol, lead, PCBs, dioxins, furans and organochlorine pesticides have decreased since pre-1991.
3. Signs of urban activity in the estuary are evident in elevated levels of some contaminants, such as PAHs dioxins, and furans, particularly in the suspended and bed sediment, compared to upstream levels.
4. With the projected growth in population in the lower Fraser River (by about 50% in the next 20 years [GVRD, 1997]), stress on the aquatic ecosystem of the estuary from contaminants, such as PAHs, is likely to grow.

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